New Horizons in Science and Engineering Education

The advent of technologies that support distance education and the demands of science and engineering (S&E)-related business and industry (e.g., information technology (IT) and bioinformatics) have been accompanied by the development of alternative mechanisms of delivering higher education, such as industrial learning centers and distance education. An increasing number of people are taking advantage of these alternatives either to enter new fields or to upgrade their skills in existing but rapidly changing fields. Many of the mechanisms, whether offered through traditional institutions (whose data are captured in national education surveys) or outside those institutions, could be defined as within the realms of continuing education or workplace training.

Industrial Learning Centers

Currently, approximately 2,000 industrial learning centers exist in the United States (compared with 400 in 1986), and this number will likely continue to increase rapidly. In general, these centers serve employees within a specific company or industry and are business management oriented. Some large industries, however, have internal training at the level of higher education in engineering and design. For example, the so-called "Motorola University" has an annual $2 billion budget (similar to that of the University of Indiana and Purdue University) and contracts with 1,200 faculty worldwide. These faculty teach business and engineering wherever Motorola is designing innovative products

Many industrial centers are partnered with traditional institutions of higher education and use traditional courses and university faculty to supplement industry-developed training courses (Meister 2001). For example, Motorola University has partnerships with traditional institutions for sharing technology, faculty, and facilities. Motorola is part of a Ph.D. program at the Indian Institute of Information Technology (IIIT) in Hyderabad, India, and degree programs at Morehouse University in Atlanta and Roosevelt University in Chicago. At the associate level, Motorola University works with faculty from Pretoria University's engineering school in South Africa (Wiggenhorn 2000).

Distance Education

Distance education is a rapidly growing and relatively unregulated aspect of higher education. In 2001, the Regional Accrediting Commissions issued their first set of guidelines for the evaluation of electronically offered degree and certificate programs (Regional Accrediting Commissions 2001). Comprehensive data are not available on the number of undergraduate and graduate S&E degrees or the number of programs fully or partially offered through distance education. However, interest in delivering and taking S&E courses and entire programs via distance education is growing (Office of Government and Public Affairs 2000). In 1997, more than 50,000 different on-line courses were offered by postsecondary institutions; 91 percent were college-level credit courses. Approximately 1.6 million people registered for on-line courses in 1998, 82 percent in college-level credit courses at the undergraduate level (University Continuing Education Association 2000). In many ways, these programs are comparable to correspondence programs offered either by for-profit institutions, such as the International Correspondence Schools, or by traditional universities through their correspondence or continuing education units. In IT-related certification programs, this method of delivering postsecondary education may be one of the dominant modes, at least on an international basis.

Undergraduate S&E Students and Degrees in the United States

Key challenges for undergraduate education in S&E include preparing teachers for K–12 and college levels (Committee on Science and Mathematics Teacher Preparation (CSMTP) 2001), preparing scientists and engineers to fill needed workforce requirements and provide the capacity for long-term innovation (Romer 2000; NSTC 2000), providing understanding of basic science and mathematics concepts for all students, and measuring what students learn (National Center for Public Policy and Higher Education 2000). These challenges relate to the nation's ability to retain its innovation capacity and international position in S&T.

The need for undergraduate teaching that could attract and retain students in S&E fields has been widely noted and discussed (National Commission on Mathematics and Science Teaching for the 21st Century 2000). Professional associations (Gaff et al. 2000; Sigma Xi 1999), private foundations (Kellogg Commission on the Future of State and Land-Grant Universities 1997), public officials (National Governors Association 2001), and universities themselves (NSF/EHR Advisory Committee 1998) have each expressed concern regarding the delivery of undergraduate education.

The nation must also meet its growing need for K–12 teachers, particularly in mathematics and science. Recent studies indicate that in the upcoming decade, the nation's school districts will need to hire 2.2 million new teachers (U.S. Department of Education 1999), including 240,000 middle and high school mathematics and science teachers (National Commission on Mathematics and Science Teach-

Certificate Programs

Three types of certificate programs are described below, based on mode of delivery (i.e., university based, community college based, or exam based).

University Based

A recent survey by the Council of Graduate Schools revealed that of the 179 university-based certificate programs reported, 34 percent were in engineering-, health-, or science-related fields, and 15 percent were in computing (Patterson 1999, 1998). The council is considering mechanisms for accrediting these university-based certificate programs and has divided them into three categories:

- **Specialty**—do not require a prior degree, are typically narrow in scope, and are oriented toward nontraditional students hoping to develop or upgrade career-related skills.
- **Professional**—require a prior degree and are typically designed to upgrade the licensure of professionals such as nurses or social workers.
- **Graduate**—augment and broaden skills and knowledge acquired through graduate degrees in the traditional disciplines and are typically interdisciplinary in scope (e.g., a graduate certificate program in environmental ethics).

Community College Based

Community colleges are an important source of science and engineering-related certification programs. (See text table 2-4.) The importance of community colleges as sources of information technology (IT)-related certificates can be estimated from the distribution of academic providers authorized by Microsoft in August 2000. Of 650 total providers, 46 percent (298) are listed as being at community colleges or two-year schools (either public/not for profit or for profit) (U.S. Department of Education 2000). (See text table 2-5.)

Exam Based

These certificates are earned by passing skill-based examinations offered globally and do not always require formal coursework, although applicants may elect to take related courses. To prove continuous updating of skills, some levels of certification require applicants to pass exams based on advances in the field. In the field of IT, for example, in 1999, 5,000 sites in 140 countries were administering an estimated 3 million assessments in 25 languages. The growth of this type of certificate for the IT industry has been rapid. More than 300 discrete certifications have been established since 1989, when the first IT certificate (Certified Novell Engineer) was issued. Approximately 1.6 million individuals worldwide earned approximately 2.4 million IT certificates by early 2000, mostly after 1997; more than 50 percent of these certificates were earned outside the United States. The exams are administered by one of three corporations (Prometric, CatGlobal, and Virtual University Enterprises), but the courses often are offered by vendors related to or licensed by the corporations whose systems are designated on the certificates (e.g., Microsoft, Cisco, Oracle, or Novell) (U.S. Department of Education 2000).

Text table 2-4.
Certificates conferred by community colleges, by field and duration: 1996–97

Field	Total	<1 year	1–2 years	>2 years
Total	166,776	69,400	85,745	11,631
S&E	60,296	24,953	32,470	2,873
Health and related sciences	56,659	23,401	30,585	2,673
Computer and information sciences	3,423	1,506	1,723	194
Other S&E-related fields	214	46	162	6
Non-S&E	106,480	44,447	53,275	8,758
Science technologies	137	78	53	6
Engineering technologies	6,203	1,705	3,705	793

SOURCE: K.A. Phillippe and M. Patton, *National Profile of Community Colleges: Trends & Statistics*, 3d ed. (Washington, DC, Community College Press, American Association of Community Colleges, 1999).

Science & Engineering Indicators – 2002

Text table 2-5.
Microsoft-authorized academic training providers, by level and control: 2000

Level and control	Number	Comment
Four-year public and not for profit	142	Approximately one-third are continuing education units.
Four-year for profit	42	Two-thirds are campuses of the University of Phoenix.
Two-year public and not for profit	298	Includes multiple campuses of large community college districts such as Houston and Allegheny (Pittsburgh).
Indeterminable post secondary status	39	Not listed in Barbett and Lin (1998) or otherwise located.
High schools	129	More than half are technical/vocational high schools.

SOURCE: U.S. Department of Education, Office of Educational Research and Improvement, *A Parallel Postsecondary Universe: The Certification System in Information Technology*, by C. Adelman (Washington, DC, 2000).

Science & Engineering Indicators – 2002

ing 2000). Of the total, 70 percent will be new to the profession, as teachers retire and the student population increases. The need for new teachers also reflects changes in course-taking patterns; student demand for high-level mathematics and science courses in high school is increasing. In addition, the need to improve teacher preparation is reflected in the number of teachers teaching in fields other than those for which they were prepared. For example, 20 percent of the middle and high school mathematics teachers hired during the 1993/94 academic year were not certified to teach mathematics (Blank and Langesen 1999). See chapter 1, “Elementary and Secondary Education,” for the magnitude of the problem of teachers teaching out of field.

Workplace needs are changing in our information- and service-oriented economy. The workforce requires people competent in mathematics, S&E, critical thinking, and the ability to work in teams (NSTC 2000). Availability of high-level, diverse personnel for basic research, discovery, and innovation depends on a sufficient pool of well-prepared students with bachelor’s degrees who are willing and able to persist through doctoral education.

The growing pressure for accountability calls for measuring the value of higher education by what students learn rather than by campus offerings. A recent study of higher education efforts found all states in the nation deficient in this area (National Center for Public Policy and Higher Education 2000).

This section gives indicators related to some of these challenges, particularly the challenge of preparing a diverse S&E workforce. These indicators include the growing diversity in undergraduate enrollment and intentions to major in S&E fields, the relatively low completion rates of S&E degrees among underrepresented minority students, the need for remediation at the college level, and recent declining trends in the number of earned degrees in most S&E fields. The section also includes recommended reforms to meet the challenges of preparing teachers and measuring student learning and describes programs showing initial signs of success.

Enrollment and Retention in S&E

Undergraduate Enrollment by Sex and Race/Ethnicity

The U.S. college-age population has grown since 1997, and the percentage of high school graduates enrolling in college is increasing for some groups. By 1999, approximately 45 percent of white and 39 percent of black high school graduates were enrolled in college, up from approximately 31 and 29 percent, respectively, in 1979. (See text table 2-6.) However, during this period, enrollment rates in higher education for Hispanic high school graduates increased only slightly, from 30 to 32 percent. An even greater racial/ethnic disparity exists with respect to Hispanic college enrollment rates based on the total college-age population (including students who did not complete high school or those who recently immigrated to the United States with little education) (Tienda and Simonelli 2001).

In the past two decades, the proportion of white students in U.S. undergraduate enrollment decreased, falling from 80 percent in 1978 to 70 percent in 1997. The proportion of underrepresented minorities increased the most, from 15.7 to 21.7 percent. Asians/Pacific Islanders increased from 2.0 to 5.8 percent, and foreign students remained approximately 2 percent of undergraduate enrollment. Women outnumber men in undergraduate enrollment for every race and ethnic group. White women constitute 55 percent of white undergraduate students, and black women constitute 62 percent of black undergraduate enrollment, which is the greatest difference found among racial groups. (See appendix table 2-8.)

Engineering Enrollment

Generally, engineering programs require students to declare their major in the first year of college, which makes enrollment an early indicator of undergraduate engineering degrees and interest in engineering careers. The annual fall

Text table 2-6.
Enrollment rates of high school graduates in higher education, by race/ethnicity: 1979–99

Race/ethnicity	1979	1989	1999
Total	31.2	38.1	43.7
White	31.3	39.8	45.3
Black	29.4	30.7	39.2
Hispanic	30.2	28.7	31.6

NOTE: Data are enrollment as a percentage of all 18- to 24-year-old high school graduates.

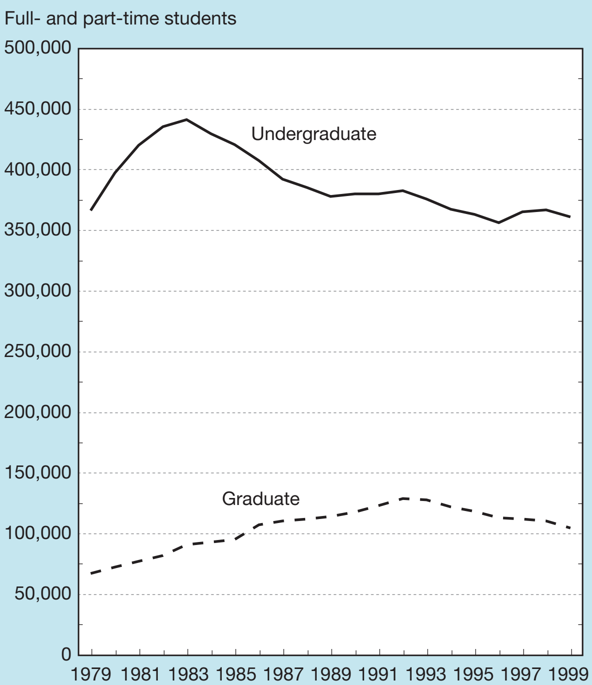
See appendix table 2-7. *Science & Engineering Indicators – 2002* survey of the Engineering Workforce Commission (2000) obtains data on actual enrollment in graduate and undergraduate programs.

The long-term trend has been for fewer students to enter engineering programs. From 1983 to 1990, engineering enrollment decreased sharply, followed by fluctuating and slower declines in the 1990s. Trends differ by degree level. At the bachelor's degree level, undergraduate enrollment declined by more than 20 percent from 441,000 students in 1983 (the peak year) to 361,000 students in 1999. (See figure 2-7 and appendix table 2-9.) At the associate degree level, enrollment in engineering technology dropped precipitously from 1998 to 1999. The number of first- and second-year students enrolling in such programs declined by 25 and 36 percent, respectively. This associate degree level of engineering technology may be shifting somewhat to workplace training. Graduate engineering enrollment peaked in 1993 and has continued downward since. (See appendix table 2-10.)

Freshmen Intentions to Major in S&E

Whether students in the United States are interested in studying S&E fields is of growing concern. Whether women and minorities are attracted to S&E majors is also of national interest because together they make up the majority of the labor force, and they have traditionally not earned S&E degrees at the same rate as the male majority. Their successful completion of S&E degrees will determine whether there will be an adequate number of entrants into the S&E workforce in the United States. Since 1972, each fall, the Higher Education Research Institute's Freshman Norms Survey asks a national sample of first-year students in four-year colleges and universities about their intentions to major in an S&E field and their readiness for college-level S&E coursework (Higher Education Research Institute (HERI) 2001). See sidebar, "Freshman Norms Survey."

Figure 2-7.
U.S. engineering enrollment, by level: 1979–99



See appendix table 2-10. *Science & Engineering Indicators – 2002*

Retention in S&E

Although approximately 25–30 percent of students entering college in the United States intend to major in S&E fields, a considerable gap exists between freshman intentions and successful completion of S&E degrees. A National Center for Educational Statistics (NCES) longitudinal study of first-year S&E students in 1990 found that fewer than 50 percent had completed an S&E degree within five years (U.S. Department of Education (NCES) 2000).[3] Students intending an S&E major in their freshman year explore and switch to other academic departments in undergraduate education, and approximately 20 percent drop out of college. The study also shows that underrepresented minorities complete S&E programs at a lower rate than other groups. A more recent longitudinal study, from 1992 to 1998, traces freshmen retention in S&E by sex, race/ethnicity, and selectivity of the institution. See sidebar, "Retention and Graduation Rates."

Associate Degrees

Trends in S&E Associate Degrees

For more than a decade, the number of associate degrees earned in S&E has fluctuated between 20,000 and 25,000. At the associate level, computer sciences represented the most sought-after S&E field; in 1998, the 13,000 computer science degrees represented 45 percent of all S&E degrees. After a five-year decline from the peak year of 1986, the number of earned degrees in computer sciences increased at an average annual rate of 5.6 percent in the 1990s. Degrees earned in engineering technology (not included in S&E total degrees) are far more numerous than degrees in S&E fields; however, they have experienced a long, steady decline during the past two decades. At the associate level, the number of degrees earned in engineering technology dropped from more than 52,000 in 1981 to 33,000 in 1997, a 36 percent decline. (See appendix table 2-14.)

Associate Degrees by Race/Ethnicity

Trends in the number of associate degrees earned by minority students differ from overall trends. Among Asians/Pacific Islanders, growth in the number of earned computer science degrees occurred during the past several years, from 1995 to 1998; the declining trend in engineering technology was neither as continuous nor as long. Among blacks, the number of degrees earned in engineering technology remained approximately 3,000 per year for the past decade, and degrees earned in computer sciences increased slightly from 1989 to 1997, with strong growth in 1998. Trends among Hispanics showed increases in the number of degrees earned in engineer-

[3]A longitudinal study follows the same students for several years.

Freshman Norms Survey

The Freshman Norms trend data show that freshmen of every race and ethnicity have high aspirations to study science or engineering (HERI 2001). For the past few decades, approximately 30 percent of white freshmen reported their intention to major in science, engineering, mathematics, or computer sciences; a higher percentage of Asian American students intended to pursue such a major (40–50 percent). In the 1990s, more than one-third of freshmen in underrepresented minority groups intended to major in science and engineering (S&E) fields. The proportion was higher for men in every racial/ethnic group and lower for women. In the 1990s, men in every group reported increased interest in computer sciences. (See appendix table 2-11.)

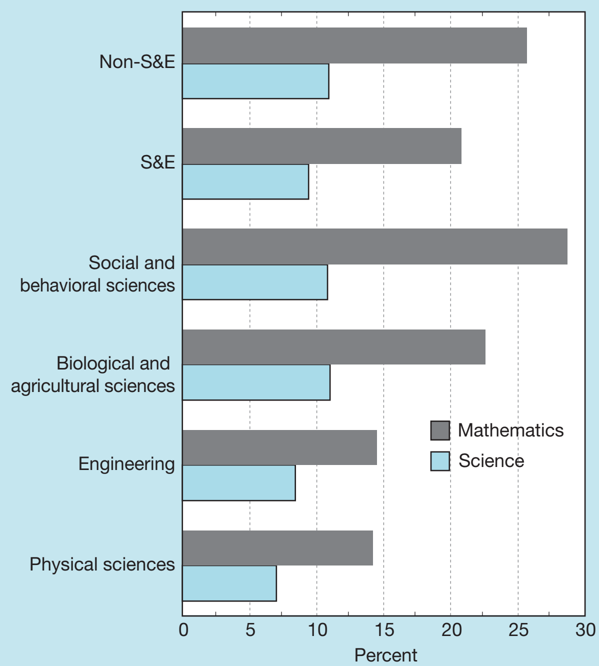
By 2000, women constituted 44 percent of the first-year college students reporting intentions to major in S&E; 56 percent were men. The data also show increasing racial diversity among freshmen intending to choose an S&E major. By 2000, underrepresented minority groups represented more than 20 percent of those intending to choose an S&E major,[*] up from 8 percent in 1971. The general trend is an increasing proportion of black and Hispanic freshmen among students intending to pursue a natural science or engineering major. (See appendix table 2-12.) For example, from 1986 to 2000, the proportion of underrepresented minorities intending to major in biological sciences or engineering rose from approximately 10 to 18 percent of first-year college students.[†] During the same period, 22–23 percent of underrepresented minority students intended to major in computer sciences, but the proportion intending to study mathematics and statistics declined from 12 to 8 percent. (See appendix table 2-12.)

*In 2000, white students constituted 66 percent of the 18- to 24-year-old population in the United States; underrepresented minority groups constituted 30 percent. (See appendix table 2-2.)

†Underrepresented minority students are not uniformly distributed across all institutions, however. They are more concentrated in minority-serving institutions: comprehensive universities and liberal arts colleges, tribal colleges, and historically black colleges and universities.

Are freshmen in the United States ready for college-level coursework? In 2000, more than 20 percent of first-year college students intending to undertake an S&E major reported that they needed remedial work in mathematics; almost 10 percent reported they needed remedial work in the sciences. This percentage has been relatively stable during the past 25 years. (See appendix table 2-13 and *S&E Indicators–2000*, appendix table 2-12.) There are some differences, however, by field of intended major. Students intending to major in the physical sciences and engineering report a lesser need for remedial work than students in other fields. In contrast, students intending to major in social and biological sciences, as well as in non-S&E fields, report more need for remedial work. (See figure 2-8.)

Figure 2-8.
Freshmen reporting need for remedial work in science or mathematics, by intended major: 2000



See appendix table 2-13. *Science & Engineering Indicators – 2002*

ing technology until 1995, followed by three consecutive years of decline and strong growth in computer sciences in the 1990s but from a low base. The number of degrees earned by American Indians/Alaskan Natives increased in all S&E fields from a very low base in 1985. (See appendix table 2-15.)

Although the proportion of degrees earned by students from underrepresented minority groups continues to increase slightly at all levels of higher education, the proportion of degrees earned at the associate level by these groups is considerably higher than that at the bachelor's or more advanced levels. The proportion of social science degrees earned by these groups at the associate level has traditionally been high (25–28 percent), and the proportion of computer science degrees earned by these students has almost doubled since 1985. (See appendix table 2-15.) In 1998, these students earned approximately 23 percent of the mathematics and computer science degrees at the associate level, a far higher percentage than at the bachelor's or more advanced levels of higher education. At the advanced levels, the percentage of S&E degrees earned by underrepresented minorities drops off,

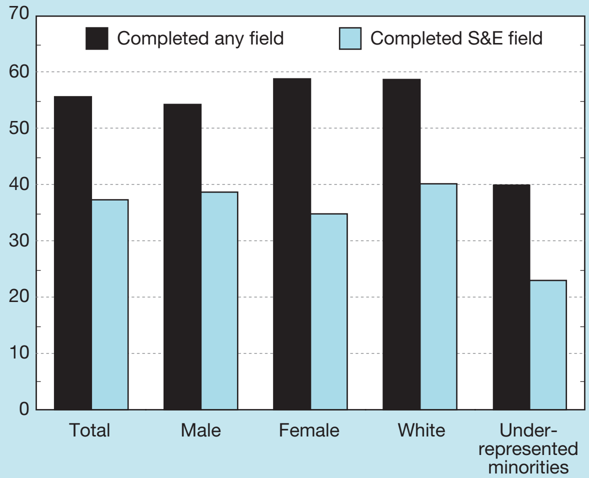
Retention and Graduation Rates

The Center for Institutional Data Analysis and Exchange (C-IDEA 2000) at the University of Oklahoma recently released a report of its longitudinal study, conducted from 1992 to 1998, of a cohort of college students. The study aimed to gather benchmark statistics on retention rates in science, mathematics, engineering, and technology disciplines. The study surveyed 119 colleges and universities ranging from small to large, liberal admission to highly selective admission, and bachelor's degree–only to doctorate-granting institutions.

In 119 colleges and universities, about 25 percent of all entering first-time freshmen in 1992 declared their intention to major in a science and engineering (S&E) field. By their second year, 33 percent of these students had dropped out of an S&E program. After six years, 38 percent had completed an S&E degree. Women and underrepresented minorities dropped out of S&E programs at a higher rate than men and nonminority students. Consequently, degree completion rates in S&E fields were lower for women (35 percent) and underrepresented minorities (24 percent). (See figure 2-9.)

The study found that retention rates of S&E majors also differ by institution. Specifically, retention rates are higher at more selective institutions, institutions with fewer part-time undergraduate students, and research institutions that also award postgraduate (master's and doctoral) degrees.

Figure 2-9.
Graduation rates and S&E completion rates of 1992 freshmen intending S&E major, by sex and race/ethnicity



NOTES: Study covers first-time college freshmen with intentions to major in S&E fields entering in 1992 and completing bachelor's degree by 1998. Underrepresented minorities include black, Hispanic, and American Indian/Alaskan Native.

SOURCE: Center for Institutional Data Exchange and Analysis, *1999–2000 SMET Retention Report*, University of Oklahoma (2000).

Science & Engineering Indicators – 2002

particularly in natural sciences and engineering (NS&E). In contrast, the decline in the percentage of degrees earned by underrepresented minorities at the advanced levels is smaller in social sciences and non-S&E fields. (See figure 2-10.)

Bachelor's Degrees

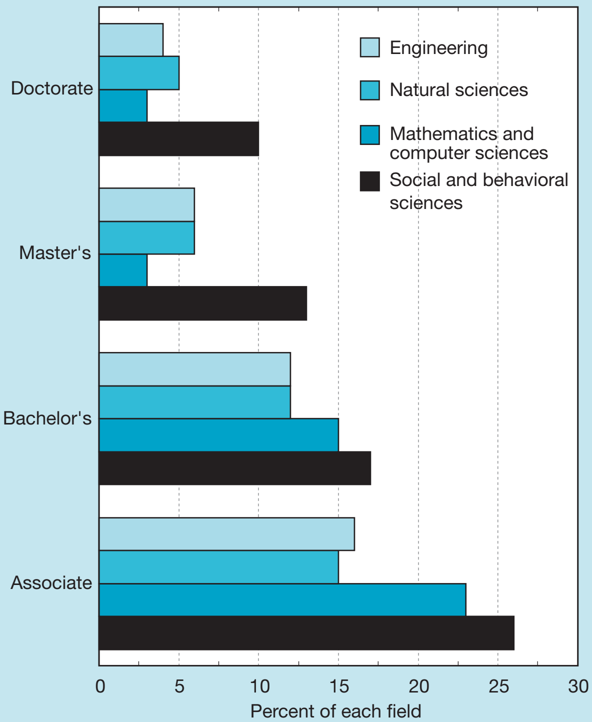
Percentage of Bachelor's Degrees in S&E Fields

Are college students earning the same percentage of bachelor's degrees in S&E fields as in the past, or have more students switched to non-S&E fields? From 1975 to 1998, the ratio of overall S&E degrees to total degrees remained approximately 33 percent. The percentages in fields within S&E, however, shifted during this period. In 1986, the year in which most S&E degrees were earned, engineering represented 8 percent of all bachelor's degrees earned, followed by a long, slow decline to 5 percent in 1998 (NSF/SRS 2001c). Since 1986, the percentage of bachelor's degrees earned by undergraduates has also declined slightly in physical sciences, mathematics, and computer sciences. In contrast, since 1986, the percentage of bachelor's degrees awarded in social and behavioral sciences and in biological sciences has increased. (See text table 2-7.)

Degree Trends

The number of overall S&E bachelor's degrees increased in the past two decades and leveled off in the late 1990s. However, the composite rise represents divergent trends in various fields. Biological and agricultural sciences are the only fields that show continuous increases in the number of degrees earned throughout the 1990s. Trends in biological sciences show a long, slow decline in the number of degrees earned in the 1980s but indicate a reversal of this trend in the early 1990s, which continued throughout the decade. The number of degrees earned in psychology increased in the 1990s but leveled off in 1997. In all other S&E fields, the number of degrees earned was either stable or declined. For two decades, students earned a relatively stable number of degrees in the physical sciences and mathematics, with slight declines in mathematics in the past few years. The number of degrees earned in computer sciences peaked in 1986, declined until the early 1990s, and then fluctuated in that decade, with a slight increase in 1997–98. The number of degrees earned in social sciences strongly increased in the 1980s, peaked in 1993, and then declined and leveled off. The number of engineering degrees earned peaked in 1986, declined sharply until 1990, fluctuated within that decade, and declined again in 1998. (See NSF/SRS 2001c and figure 2-11.)

Figure 2-10.
S&E degrees earned by underrepresented minorities within each field, by level: 1998–99



NOTES: Doctoral-level degrees are 1999 data; all other levels use 1998 data. Natural sciences include physics, chemistry, astronomy, and earth, atmospheric, ocean, biological, and agricultural sciences. Underrepresented minorities include black, Hispanic, and American Indian/Alaskan Native.

See appendix tables 2-15, 2-17, 2-23, and 2-25.

Science & Engineering Indicators – 2002

Text table 2-7.
Bachelor's degrees earned in S&E fields: various years
(Percentages)

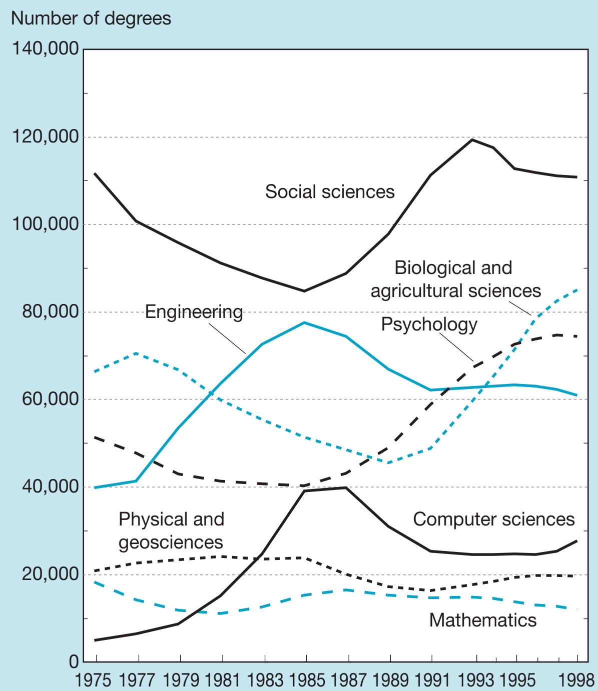
Field	1975	1985	1998
All S&E[a]	33.7	33.5	32.6
NS&E	16.1	20.9	17.1
Physical sciences	1.7	1.6	1.3
Earth, atmospheric, and ocean sciences	0.5	0.8	0.4
Biological and agricultural sciences	7.1	5.2	7.1
Mathematics	2.0	1.6	1.0
Computer sciences	0.5	3.9	2.3
Engineering	4.3	7.8	5.1
Social and behavioral sciences	17.5	12.6	15.4

NS&E = natural science and engineering

[a]Percentage of all bachelor's degrees.

See appendix table 2-16. *Science & Engineering Indicators – 2002*

Figure 2-11.
Bachelor's degrees earned in selected S&E fields: 1975–98



NOTE: Geosciences include earth, atmospheric, and ocean sciences.

See appendix table 2-16. *Science & Engineering Indicators – 2002*

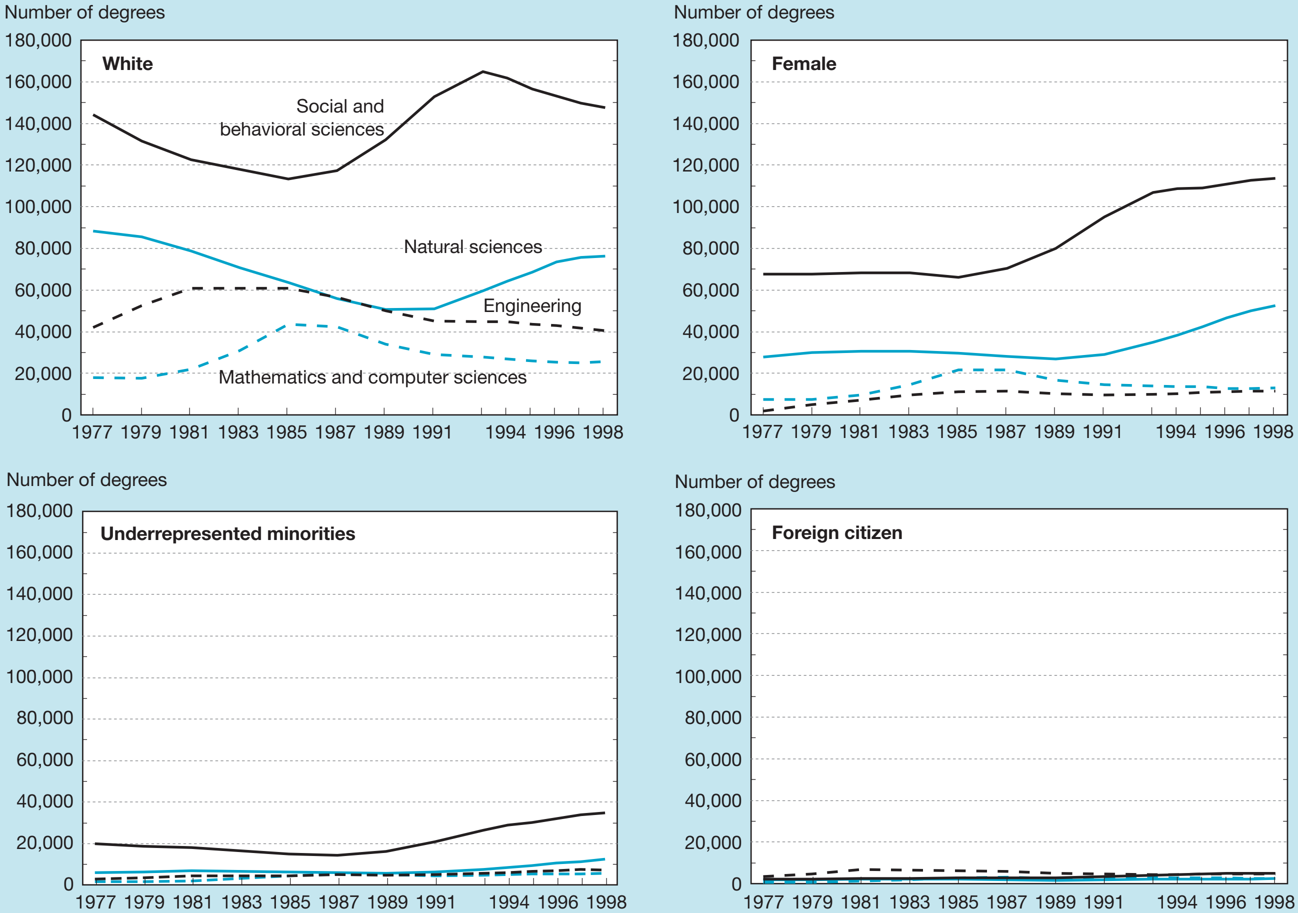
Bachelor's Degrees by Sex

The rise in the number of degrees earned in biological sciences and psychology in the 1990s reflects a high proportion of women entering these fields (48 percent in biological sciences and 72 percent in psychology in 1998), thus offsetting the decline expected from the shrinking college-age cohort. The declining number of degrees earned in most other S&E fields is influenced by both the shrinking college-age cohort and an underrepresentation of women and minorities in these fields. Women and minorities continue to be underrepresented in engineering and computer sciences. (See appendix table 2-16.) The sharp decline in the number of degrees earned in computer sciences is probably a combination of demographics and other readily available (non-degree-granting) modes of acquiring skills in this field, such as workplace training, certificate programs, and on-line courses. See sidebars, "New Horizons in Science and Engineering Education" and "Certificate Programs." (See appendix table 2-1.)

Bachelor's Degrees by Race/Ethnicity

In contrast to overall trends, all minority groups showed an increasing or stable number of degrees earned in most S&E fields in the 1990s. The number of degrees earned by Asians/Pacific Islanders increased in all S&E fields except mathematics. Underrepresented minority groups show a stable number of degrees earned in physical sciences, mathematics, and computer sciences and decade-long increases in degrees earned in social and behavioral sciences, biological sciences, and engineering. In 1998, their number of degrees earned lev-

Figure 2-12.
Bachelor's degrees in S&E fields, earned by selected groups



NOTES: Data for 1983 are estimated. Natural sciences include physics, chemistry, astronomy, and earth, atmospheric, ocean, biological, and agricultural sciences. Underrepresented minorities include black, Hispanic, and American Indian/Alaskan Native. White and underrepresented minorities include U.S. citizens and permanent residents. Foreign citizen includes temporary residents.

See appendix tables 2-16 and 2-17.

Science & Engineering Indicators – 2002

eled off only in engineering, after a decade-long increase. (See appendix table 2-17 for data by field and figure 2-12 for degree trends of selected groups.)

Bachelor's Degrees by Citizenship

Foreign students earn a small percentage (3.6 percent) of S&E bachelor's degrees, a number barely visible on a graph. (See figure 2-12.) Trends in degrees earned by foreign students show increases in the number of bachelor's degrees in social sciences, with slight increases in biological sciences and psychology; fluctuating and declining degrees in engineering; and declining degrees in physical sciences, mathematics, and computer sciences. Foreign students in U.S. institutions earn approximately 7–8 percent of bachelor's degrees awarded in mathematics, computer sciences, and engineering—somewhat lower than the proportion of degrees earned by foreign students in U.K. institutions. In 1999, foreign students in U.K. universities earned almost 30 percent of the bachelor's degrees awarded in engineering and 12 percent of those awarded in mathematics and computer sciences. (See text table 2-8.)

U.S. Participation Rates in Bachelor's Degrees and S&E Degrees by Sex and Race/Ethnicity

Traditionally, the United States has been among the leading nations of the world in providing broad access to higher education. The ratio of bachelor's degrees earned in the United States to the population of the college-age cohort is relatively high: 35 per 100 in 1998. The ratio of natural science and engineering (NS&E) degrees to the population of 24-year-olds in the United States has been between 4 and 5 per 100 for the past several decades and reached 6 per 100 in 1998. Several Asian and European countries have higher participation rates. (See appendix table 2-18 and "International Comparison of Participation Rates in University Degrees and S&E Degrees.")

Text table 2-8.
Bachelor's degrees earned by foreign students in S&E fields, United Kingdom and United States

Field	Degrees: All students	Degrees: Foreign students	Percent foreign
United Kingdom (1999)			
Total S&E degrees	89,520	12,584	14.1
Natural sciences	32,226	2,223	6.9
Mathematics and computer sciences	14,630	1,708	11.7
Social and behavioral sciences	20,652	2,082	10.0
Engineering	22,012	6,571	29.9
United States (1998)			
Total S&E degrees	411,286	14,728	3.6
Natural sciences	104,852	2,391	2.3
Mathematics and computer sciences	39,404	2,585	6.6
Social and behavioral sciences	206,160	5,109	2.5
Engineering	60,870	4,643	7.6

NOTES: U.S. data on foreign students include temporary residents only. Natural sciences include physics, chemistry, astronomy, and earth, atmospheric, ocean, biological, and agricultural sciences.

SOURCES: United Kingdom—Higher Education Statistics Agency, unpublished tabulations (2001); and United States—appendix table 2-17.

Science & Engineering Indicators – 2002

National statistics on participation rates in S&E fields, however, are not applicable to all minority groups in the United States. The gap in educational attainment between whites and racial/ethnic minorities continues to be wide, particularly in participation rates in S&E fields. In 1998, the ratio of college degrees earned by underrepresented minorities to their college-age populations was 18 per 100, and the ratio of NS&E degrees was 2.6 per 100. Comparison of participation rates in 1980 and 1998 shows considerable progress for underrepresented minority groups in earning bachelor's degrees, but their rate of earning NS&E degrees is still less than one-half the rate of the total population. (See text table 2-9.) In contrast, Asians/Pacific Islanders have considerably higher-than-average achievement: the ratio of bachelor's degrees earned to the college-age population is 47 per 100 and that of NS&E degrees to the college-age population is 14.7 per 100.

One partial explanation given for this gap in educational attainment is that the cost barrier for students from low-income families to attend college is increasing; the needs-based system of financial aid for college students has shifted to a greater reliance on loans, tuition tax credits, and merit-based scholarships (The College Board 2000). The cost of higher education to the middle and upper income groups of the population in terms of percentage of their income consumed has not changed appreciably, whereas the percentage of income necessary for people in the lower income group to earn a college degree has risen considerably (National Governors Association (NGA) 2001).

Recommended Reforms

Recommendations have been offered for meeting the challenges of S&E higher education. They are outlined succinctly in recent studies by the National Research Council (Committee on Undergraduate Science Education 1999; CSMTP 2001) and NSF (*Shaping the Future* 1998). The recommendations relate to both institutionwide and departmental reforms:

- ♦ **Take an institutional approach to change.** The undergraduate education responsibilities of the university should be given high priority by accrediting agencies, discipline and higher education professional organizations, faculty, departments, and university administrators.
- ♦ **Give all students math and science literacy.** Postsecondary institutions should provide all students with the strong foundation in mathematics and sciences needed to function in an increasingly technologically complex world and prepare students for careers in S&E.
- ♦ **Help faculty improve their teaching.** Faculty and future faculty need to be aware of the latest research in teaching and learning, such as the benefits of incorporating student inquiry and teamwork into their regular classroom practices, collaborative and active learning, discovery- and inquiry-based courses, and incorporating real-world problems into the classroom by asking students to help frame problems and contribute solutions.
- ♦ **Increase undergraduate research.** Develop opportunities for all students to engage in undergraduate S&E-related research with particular attention to students majoring in S&E fields, students from groups traditionally underrepresented in these fields, and students preparing to be teachers. Faculty should bring the excitement of new research findings into both lower and upper division courses.
- ♦ **Expand interdisciplinary teaching.** Increase multidisciplinary perspectives in science and mathematics undergraduate programs to reflect the increased workplace

Text table 2-9.
Ratio of total bachelor's degrees and S&E bachelor's degrees to the 24-year-old population, by sex and race/ethnicity: 1980 and 1998

Race/ethnicity and sex	Total 24-year-old population	Total bachelor's degrees	Natural science degrees	Social and behavioral science degrees	Engineering degrees	Ratio to 24-year-old population: Bachelor's degrees	NS&E degrees	Social and behavioral science degrees
1980								
Total	4,263,800	946,877	110,468	132,607	63,717	22.2	4.1	3.1
Sex								
Male	2,072,207	474,336	70,102	64,221	56,654	22.9	6.1	3.1
Female	2,191,593	472,541	40,366	68,386	7,063	21.6	2.2	3.1
Race/ethnicity								
White	3,457,800	807,509	100,791	122,519	60,856	23.4	4.7	3.5
Asian/Pacific Islander	64,000	18,908	3,467	2,499	3,066	29.5	10.2	3.9
Underrepresented minority	892,000	97,539	8,915	22,782	4,464	10.9	1.5	3.9
Black	545,000	60,779	4,932	16,352	2,449	11.2	1.4	3.0
Hispanic	317,200	33,167	3,646	5,748	1,820	10.5	1.7	1.8
American Indian/Alaskan Native	29,800	3,593	337	682	195	12.1	1.8	2.3
1998								
Total	3,403,039	1,199,579	144,441	185,263	60,914	35.3	6.0	5.4
Sex								
Male	1,714,571	525,714	78,906	71,740	49,575	30.7	7.5	4.2
Female	1,688,468	673,865	65,535	113,523	11,339	39.9	4.6	6.7
Race/ethnicity								
White	2,251,292	878,018	101,967	147,707	40,533	39.0	6.3	6.6
Asian/Pacific Islander	149,413	69,988	15,001	12,565	7,002	46.8	14.7	8.4
Underrepresented minority	1,002,334	181,709	18,424	34,836	7,396	18.1	2.6	3.5
Black	473,402	95,878	9,713	18,667	3,018	20.3	2.7	3.9
Hispanic	497,620	78,125	7,881	14,719	4,125	15.7	2.4	3.0
American Indian/Alaskan Native	31,312	7,706	830	1,450	253	24.6	3.5	4.6

NS&E = natural science and engineering

NOTES: Natural sciences include physics, chemistry, astronomy, and earth, atmospheric, ocean, biological, and agricultural sciences, as well as mathematics and computer sciences. The ratios are the number of degrees to the 24-year-old population. Population data are for U.S. residents only and exclude members of the Armed Forces living abroad.

SOURCES: U.S. Bureau of the Census, Population Division, *U.S. Population Estimates by Age, Sex, Race, and Hispanic Origin: 1980 to 1999* (Washington, DC, 2000); National Science Foundation, Science Resources Studies (NSF/SRS), *Science and Engineering Degrees 1966–1998*, NSF 01-325 (Arlington, VA, 2001); and appendix table 2-17.

Science & Engineering Indicators – 2002

emphasis on interdisciplinary approaches, such as computational chemistry and bioengineering.

♦ **Increase partnerships.** Include appropriate industry and other potential employers in planning curricular changes.

Several organizations have made recommendations regarding their responsibilities for preparing high-quality K–12 teachers in science and mathematics, including institutions of higher education (Association of American Universities 1999; American Association of State Colleges and Universities 1999), business groups (National Alliance of Business 2001), and professional societies (CSMTP 2001). Although the strategies to meet their responsibilities differ, their goals to establish exemplary models of teacher preparation whose success can be widely replicated and to find ways to attract additional qualified candidates to teaching are similar.

Strategies offered by research universities and state colleges and universities include the following:

♦ Make teacher education a top campus priority and a joint endeavor between faculty in education programs and faculty in other academic disciplines.

♦ Create and sustain partnerships with schools, state departments of education, informal education providers such as zoos and museums, and local businesses and industries.

♦ Offer undergraduate research experience to future elementary and secondary mathematics and science teachers.

♦ Create sound alternatives for mathematics and science majors to obtain teacher certification.

National agencies such as the Department of Education and NSF have begun funding various support programs to

Meeting the Challenge of Teacher Preparation

In 1998, the Department of Education established Teacher Quality Enhancement grants to encourage comprehensive approaches in improving the quality of teacher preparation programs. Many of these grants are five-year awards with cumulative multimillion-dollar funding. Twenty-five awards were made in fall 1999, and eight awards were made in 2000. Six of these awards were given to institutions that had already begun the process of reform under the National Science Foundation's Collaboratives for Excellence in Teacher Preparation (CETP) program, which was initiated in 1992.

The 32 systemic (regional in scope) and institutional (concentrated in one or a few related institutions) CETP projects awarded as of fiscal year 2000 included 250 institutions of higher education (13 percent of the projects related to doctoral degrees, 30 percent to two-year degrees, 31 percent to master's or bachelor's degrees) and 89 to public high schools.

Data collected in spring 2000 by the systemic projects reveal that 4,050 faculty and 4,979 teachers were involved in the CETP projects' efforts to produce teachers who are prepared to teach mathematics and science and to teach and use information technology. The institutions involved in the CETP program are distributed within 22 states and produce 38 percent of the teachers in the states in which they operate. Of the 15,896 1999 CETP graduates who have been tracked, 72.4 percent entered the teaching profession, and 17.7 percent were still attending school—most presumably in postbaccalaureate programs necessary for certification in their state (NSF/EHR 2000).

Evaluation of these programs has shown that, generally, the concerted efforts to improve teacher education in mathematics and science have been effective:

- Higher student achievement was measured in schools served by the Philadelphia CETP (Temple University). From 1996 to 1999, the Stanford Achievement Test (SAT-9) math and science average test scores and gains for 4th-grade classes in which CETP undergraduates taught during their practica exceeded the citywide average.
- Retention of new teachers in the Montana CETP Early Career Support project improved. The attrition rate from teaching for the more than 120 beginning teachers in the Early Career program was approximately 3 percent, far below the national average of 30 percent.
- An increase in minority teachers resulted from the efforts of the Montana CETP. In 1992, before CETP was instituted, 5 of the 1,500 mathematics and science teachers in the state of Montana were Native American. By the end of the project in 1999, 11 American Indians had graduated certified to teach mathematics or science, and 77 more were in the pipeline, attending tribal colleges or university campuses for secondary mathematics or science certification.

catalyze efforts to improve teacher preparation. See sidebar, "Meeting the Challenge of Teacher Preparation." Alternative certification programs to increase the nation's supply of math and science teachers are aimed at those already in S&E careers or S&E majors who would like to enter K–12 teaching (Feistritzer and Chester 2000; Urban Institute 2000). See sidebar, "Alternative Certification for K–12 Teachers."

National data are scarce with regard to how students go through higher education, the extent of participation, and learning outcomes. See sidebar, "Special New Programs," for information about some funding programs and institutions attempting to implement recommended reforms. Changes include focusing on learning outcomes in undergraduate education, increasing diversity of the S&E workforce, incorporating recent advances in teaching and learning into the undergraduate classroom, and augmenting research experiences for undergraduates.

Graduate S&E Students and Degrees in the United States

Overall Trends in Graduate Enrollment

Is the United States educating an adequate number of bachelor-level S&E majors who are willing and able to pursue advanced degrees in S&E? Has access to graduate programs improved for women and underrepresented minorities? This section presents trends in graduate enrollment: strong growth in foreign student enrollment until 1992 and declining enrollment for both U.S. and foreign citizens from 1993 to 1998. Enrollment of foreign students turned up considerably in 1999, increasing their proportion of the graduate population.

The long-term trend of increasing enrollment in graduate S&E programs in the United States persisted for several decades, peaked in 1993, declined for five years, and then increased in 1999. Trends differ somewhat across S&E fields. For example, enrollment in mathematics and computer sciences peaked in 1992, declined for three years, and then increased from 1995 onward. In contrast, the number of graduate students in engineering declined for six consecutive years (1993–98) before increasing slightly in 1999. (See appendix